Related Pending Application
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**CLAIMS:**

1. An optical device comprising:

photon generating means configured to generate photons at a photon generation portion; and

directing means provided to direct photons generated by said generating means in a predetermined direction, said directing means comprising a three dimensional cavity for confining a photon such that the photon can only occupy a discrete number of optical modes in three dimensions, the three dimensional cavity being formed within a layer or a plurality of layers, confinement in at least one lateral dimension within the plane of the layer or layers being provided by a pattern of reflective interfaces, the three dimensional cavity being formed at an irregularity in the pattern, the photon generation portion being located within the three dimensional cavity or directly above or below the three dimensional cavity.

2. An optical device comprising:

photon generating means configured to generate photons at a photon generation portion; and

directing means provided to direct photons generated by said generating means in a predetermined direction, said directing means comprising a three dimensional cavity for confining a photon such that the photon can only occupy a discrete number of optical modes in three dimensions, wherein in one of the dimensions optical confinement is non-symmetric such that the optical confinement on a first side of the cavity is weaker than that of the opposite side to direct emission from the photon generating means out through the first side of the cavity, the three dimensional cavity being formed within a layer or a plurality of layers wherein confinement in at least one lateral dimension within the plane of the layer or layers being provided by a pattern of reflective interfaces, the three dimensional cavity being formed at an irregularity in the pattern.

3. The optical device of claim 1, wherein the photon generating means is configured to generate pulses of n photons where n can be controlled and is a integer of at least 1.

4. The optical device of claim 1, wherein the generating means comprises a quantum dot.

5. The optical device of claim 1, wherein said generating means comprises a quantum dot having a first confined energy level capable of being populated by an electron and a second confined energy level capable of being populated by a hole; and

supply means for supplying carriers to the said energy levels, wherein the supply means are configured to supply a predetermined number of carriers to at least one of the energy levels to allow recombination of a predetermined number of carriers in said quantum dot to emit at least one photon.

6. The optical device of claim 4, wherein the supply means comprises incident radiation configured to excite a predetermined number of electrons and for holes into the first and second energy levels respectively.

7. An optical device comprising:

a quantum dot located within a three dimensional optical cavity configured to confine a photon to the order of the photon's wavelength in all three dimensions, the quantum dot and optical cavity being configured such that there is strong coupling between the confined electronic modes of the quantum dot and the optical modes of the cavity,

wherein the three dimensional optical cavity is provided within a layer or a plurality of layers and optical confinement in one of the dimensions within the plane of the layer or layers is provided by a pattern of reflective interfaces, the three dimensional optical cavity being formed at an irregularity in the pattern.

8. The optical device of claim 1, wherein the pattern is a two dimensional pattern.

9. The optical device of claim 1, wherein the pattern is a one dimensional pattern, confinement in the other dimension within the plane being achieved by restricting the width of the layer or layers in this dimension.

10. The optical device of claim 1, wherein confinement perpendicular to the plane of the layer or layers is provided by mirror regions located on either side of said layer or layers to define a one dimensional optical cavity.

11. The optical device of claim 1, wherein at least one of the mirror regions comprises a Bragg reflector having a stack of alternating layers.

12. The optical device of claim 11, wherein the Bragg reflector preferably comprises alternating layers of GaAs/Alox or GaAs/AlAs or $SiO_2/TiO_2$ or $Al_xGa_{1-x}As_ySb_{1-y}/AlAs_ySb_{1-y}$ (where $y = 0.5$ and $x = 0.1$), InP/InGaAsP, $InP/In_{0.52}Al_{0.48}As$ or InP/InAlox.

13. The optical device of claim 11, wherein the stack of alternating layers has from 2 to 50 periods.

14. The optical device of claim 11, wherein both of the mirror regions comprise Bragg reflectors.

15. The optical device of claim 11, wherein at least one of the mirror regions comprises a metal layer.

16. The optical device of claim 15, wherein a phase matching layer is provided between the one dimensional optical cavity and the metal layer

17. The optical device of claim 10, wherein the two mirror regions have different transparencies to the generated photons.

18. The optical device of claim 10, wherein the photon generating portion is provided at an antinode in said one dimensional optical cavity.

19. The optical device of claim 1, where there is a second irregularity in the pattern of reflecting interfaces, the irregularity being configured such that said predetermined direction is defined by said second irregularity.

20. The optical device of claim 1, wherein the number of repeats of the pattern is reduced along a predetermined direction from the three dimensional cavity such that emission is directed along this predetermined direction.

21. The optical device of claim 1, wherein the pattern of reflective interfaces is provided by a pattern of holes located in the plane of the layer or layers.

22. The optical device of claim 21, wherein the holes are arranged on a triangular, circular or rectangular lattice.

23. The optical device of claim 21, wherein the holes have a generally circular cross section

24. The optical device of claim 21, wherein the holes are a plurality of concentric circular holes, the irregularity being formed substantially at the centre of the concentric circular holes.

25. The optical device of claim 21, wherein the holes are filed with a material having a different dielectric constant to that of the material of the layer or layers.

26. The optical device of claim 9, wherein the pattern of reflective interfaces is provided by a pattern of holes located in the plane of the layer or layers, and wherein the holes extend through at least one of the mirror regions.

27. The optical device of claim 26, wherein the holes extend through both mirror regions.

28. The optical device of claim 1, wherein the reflective interfaces are provided by a plurality of pillars located in the plane of said layer or layers.

29. A method of operating an optical device, the optical device comprising:

a quantum dot located in a three dimensional optical cavity configured to confine a photon to the order of the photon wavelength in all three dimensions, the quantum dot and optical cavity being configured such that there is strong coupling between the confined electronic modes of the quantum dot and the optical modes of the cavity,

wherein the three dimensional optical cavity is provided within a layer or a plurality of layers and optical confinement in one of the dimensions within the plane of the layer or layers is provided by a pattern of reflective interfaces, the three dimensional optical cavity being formed at an irregularity within the pattern,

the method comprising the steps of:

irradiating the device with a main beam of radiation having an energy which is substantially equal to that of the cavity mode in the absence of the quantum dot, and selectively illuminating the device with a control beam comprising at least one photon having an energy which is equal to one of the coupled modes between the three dimensional cavity and the dot, in order to control the transmission or reflection of the main beam.

30. A method of forming an optical device comprising the steps of:

forming a first mirror region;

forming a cavity region having a quantum dot by:

forming a lower cavity region overlying said first mirror region;

forming a quantum dot overlying said lower cavity region;

forming an upper cavity region overlying said lower cavity region to encapsulate said quantum dot;

patterning the cavity region to form a plurality of reflecting interfaces, a three dimensional cavity being formed at an irregularity in the pattern, wherein the three dimensional cavity is configured to confine a photon to a length scale of the order of the photon wavelength such that the photon can only occupy a discrete number of optical modes in three dimensions.

31. A method of forming a photon emitter comprising the steps of:

forming a first mirror region;

forming a cavity region having a quantum dot by:

forming a lower cavity region overlying said first mirror region;

forming a quantum dot overlying said lower cavity region;

forming an upper cavity region overlying said lower cavity region to encapsulate said quantum dot;

patterning the cavity region to form a plurality of reflecting interfaces

forming a second mirror region overlying the patterned cavity region, wherein the first mirror region, second mirror region and pattern of interfaces are configured to define a three dimensional cavity at an irregularity in the pattern, wherein the three dimensional cavity is configured to confine a photon to a length scale of the order of the photon wavelength such that the photon can only occupy a discrete number of optical modes in three dimensions.

32. The method of claim 30, wherein the step of patterning the cavity region comprises the step of etching holes through said cavity region.

33. The method of claim 32, wherein said holes extend through the first mirror region.

34. The method of claim 30, wherein the second mirror region is also patterned with said holes.

35. The method of claim 30, wherein either of the first or second mirror regions are etched to form a window for receiving an optical fibre.

36. The method of claim 30, wherein said step of forming the cavity region comprises the steps of:

forming a lower cavity layer;

forming a quantum dot layer, overlying and in contact with said lower cavity layer, said quantum dot layer comprising 0.5 to 10 monolayers and having a different lattice constant to that of said lower cavity layer, such that said quantum dot layer forms a plurality of islands during growth; and forming a second cavity layer, overlying and in contact with said first cavity layer and said dot layer.

37. The method of claim 36, wherein the dot layer is formed by depositing InAs, InSb, GaSb, InGaAs, InGaAsNi, GaP, InP, InGaP, InGaSb or alloys thereof.

38. The method of claim 30, wherein at least one of said mirror regions is a Bragg reflector, said Bragg reflector being formed by growing a stack of repeating semiconductor layers.

39. The method of claim 38, wherein one of said semiconductor layers comprises Alox, said Bragg reflector being formed by growing alternate layers of AlAs or InAlAs and oxidising said layers after growth of the stack is complete.